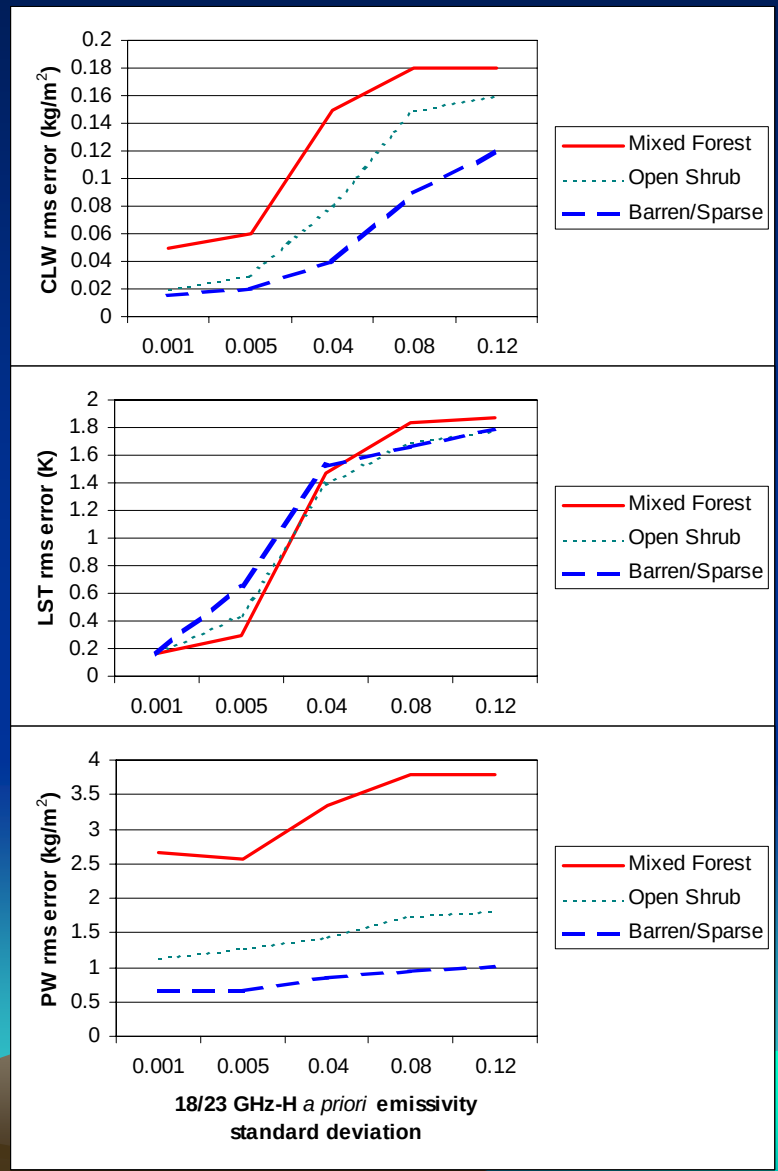
Development of a global dynamic AMSR-E land surface emissivity database

J.-L. Moncet, J. Galantowicz, P. Liang,
C. Grassotti, Y. He
AER, Inc.

C. Prigent
Observatoire de Paris, LERMA

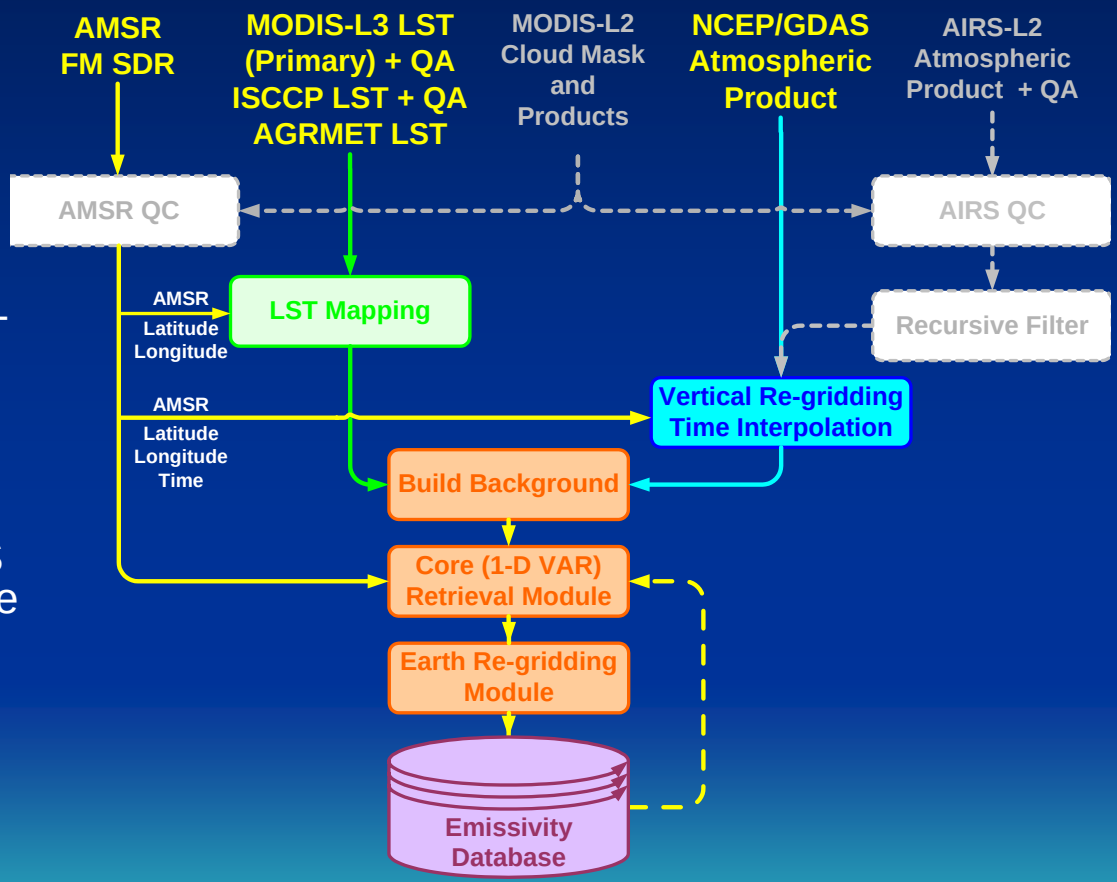
Goals

- 3 Yr effort – 2 more yrs to go
- Main goal: Provide emissivity constraint for lower tropospheric and LST retrievals over land. Critical for assimilation of satellite data in NWP model.
  - Under cloudy conditions extrapolate emissivities from clear-sky
  - For this application, a priori uncertainty on emissivities < ~0.01 is required
- Not sure that static maps of monthly averages are sufficient
  - Monthly averages may be affected by frequency of precipitation events in a particular year and do not reflect inter-annual variability
  - Best to monitor time evolution of emissivity at any given location and attempt to predict (may include surface models)
- Data is also useful for short/long term monitoring of changes in surface properties and improving understanding of physical mechanisms affecting surface radiation budget
  - System can be extended to include IR emissivities as well
- Pathfinder for future NPOESS operational system (CMIS)



System Overview

- Heritage: previous work of C. Prigent with SSM/I
  - AMSR-E adds 6 and 10 GHz
- Complements on-going work at JCSDA with AMSU (AGRMET)
- MODIS provides excellent timeliness and co-location for LST but may have its own problems (see below) and may differ from ISCCP used with SSM/I
- AIRS same – problems with AIRS retrieval over land forces us to use NWP source instead
- 1-D VAR retrieval system
  - clear/cloudy retrieval modes
  - full use of AMSR-E spectral information content
  - flexible use of atmospheric/ surface external constraint



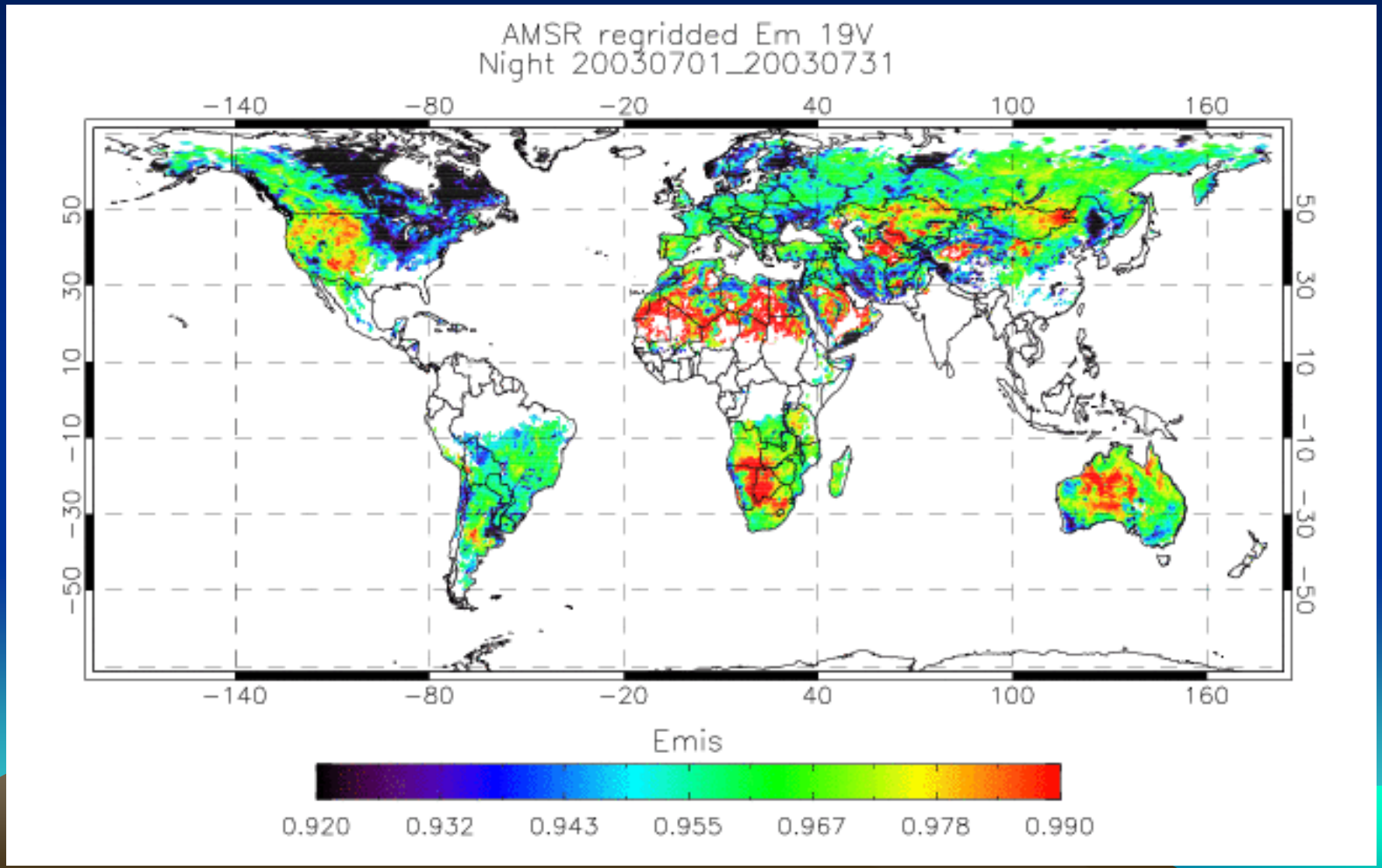
System overview

- Retrieval to be performed at all AMSR-E footprints
- Emissivity at a grid point obtained as weighted average of neighboring “high quality” FOV’s
- QC:
  - Level 2A (B01) AMSR-E QA flag
  - MODIS cloud mask/cloud product
    - Initial system used MODIS cloud mask to monitor quality of AMSR measurement (and when AIRS is used provide additional QC for AIRS product)
    - Cloud mask has deficiencies at night
  - MODIS level 3 LST flag
    - Similar to MODIS cloud mask (used as a substitute)

Emissivity Database

- 27.8 km sinusoidal grid spacing, no time averaging
- LST (+profile?)
- CLW in cloudy conditions
- Flag following situations:
  1. Inhomogeneous surface – high variability due to re-gridding
  2. Transient events (precipitation,…etc)
  3. Persistent day/night variability:
     - High penetration depth areas
     - Terrain slope (azimuthal dependence)
  4. Other:
     - Unscreened clouds (89 GHz)
     - Large PW errors (use 19, 22 and 89 GHz)
     - Missing radiometric/external data
     - Retrieval mode

19V AMSR-E Emissivity Map 07/03 (51x29 km res., nighttime only)

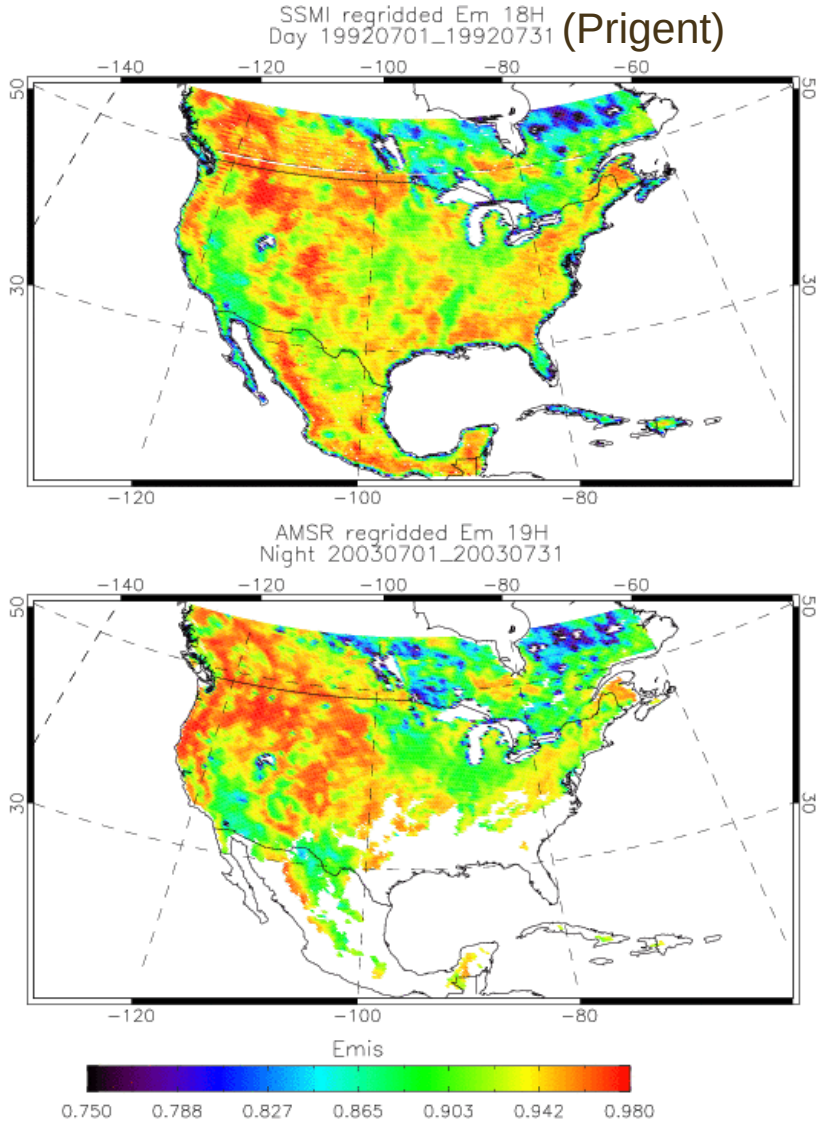


Planned verification

- No *in situ* means of validating product
- Planned verification:
  - Consistency with AMSR-SM product and previously derived SSM/I emissivities (make it part of our automated system?)
  - Time stability (outside of precipitation events)
  - Diurnal surface temperature cycle captured
  - Improvement in cloud liquid water (CLW) detection over land
    - Comparison between NOAA-16 AVHRR and retrievals with and without *a priori* local emissivity estimates
  - Radiometric and physical consistency with IR measurements

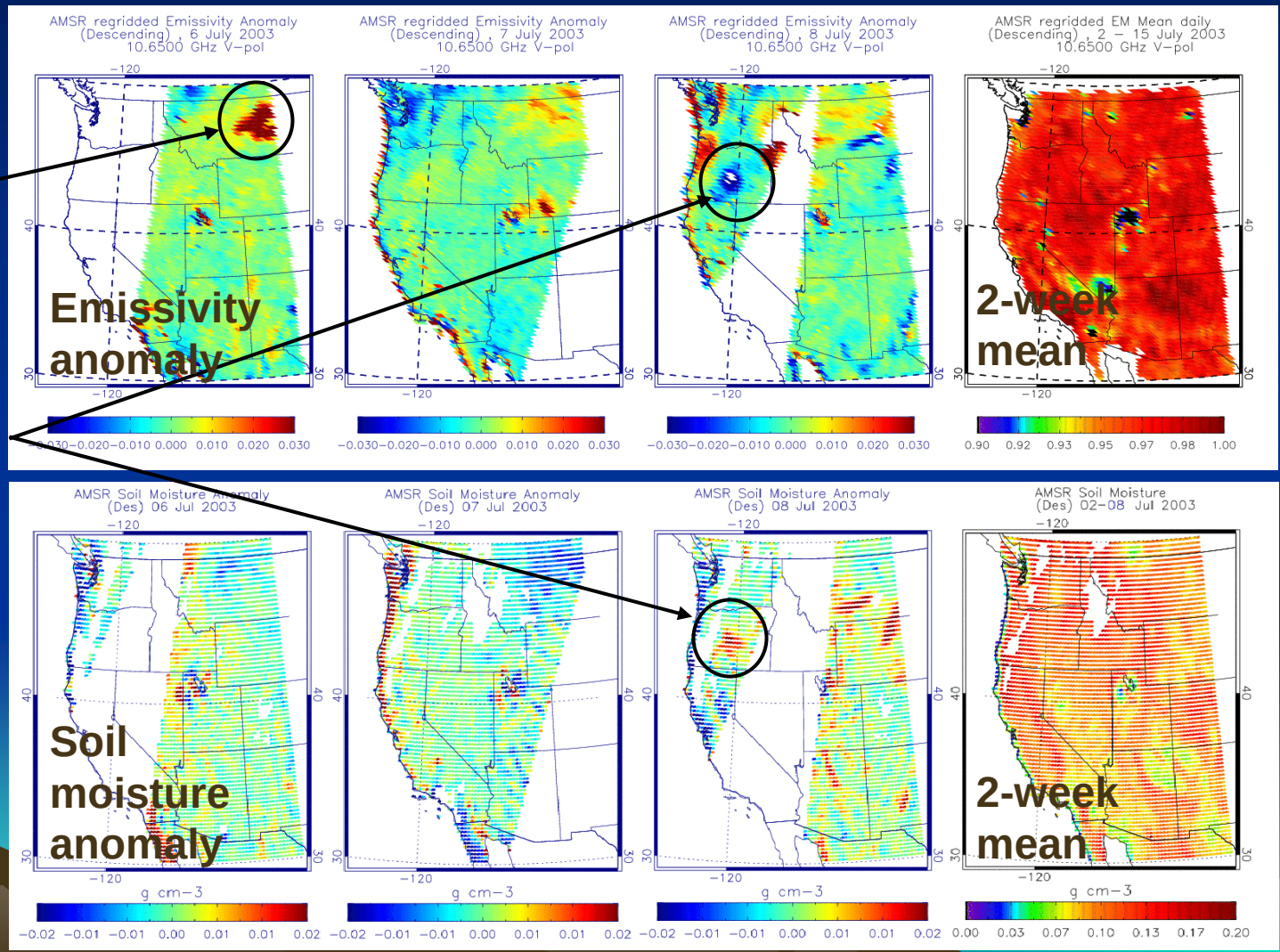
AMSR-E vs. SSM/I (19H) Comparison

- **DMSP-SSM/I (07/92):**
  - Early morning/late afternoon passes
  - ISCCP cloud mask and LST products
  - NCEP global re-analysis
- **AMSR-E (07/03):**
  - Night only (1:30am ECT)
  - MODIS LST
  - NCEP/GDAS atmosphere
- Transient events (precipitation) included in monthly means



Emissivity change detection (through time series analysis, 10V)

- Cloudy regions not filtered out => low “LST” => high estimated emissivity
- Monitoring consistency between regions of high AMSR soil moisture and low surface emissivity

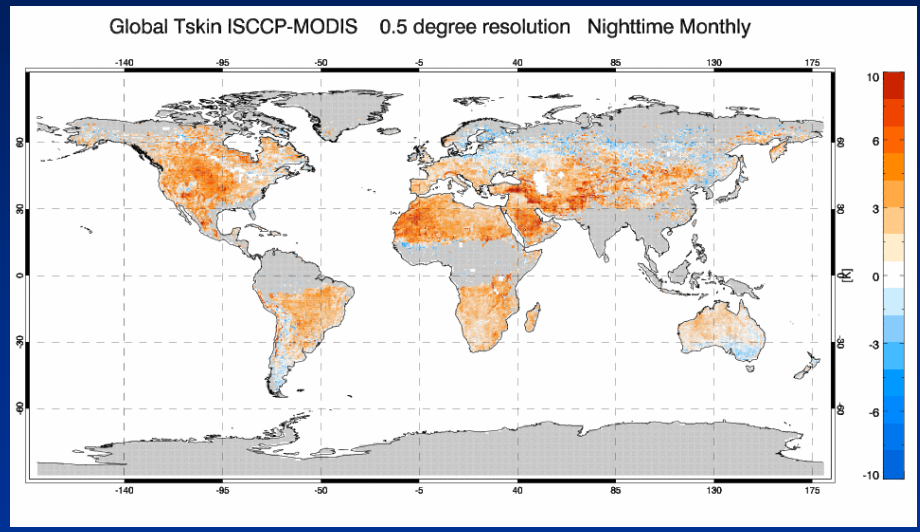


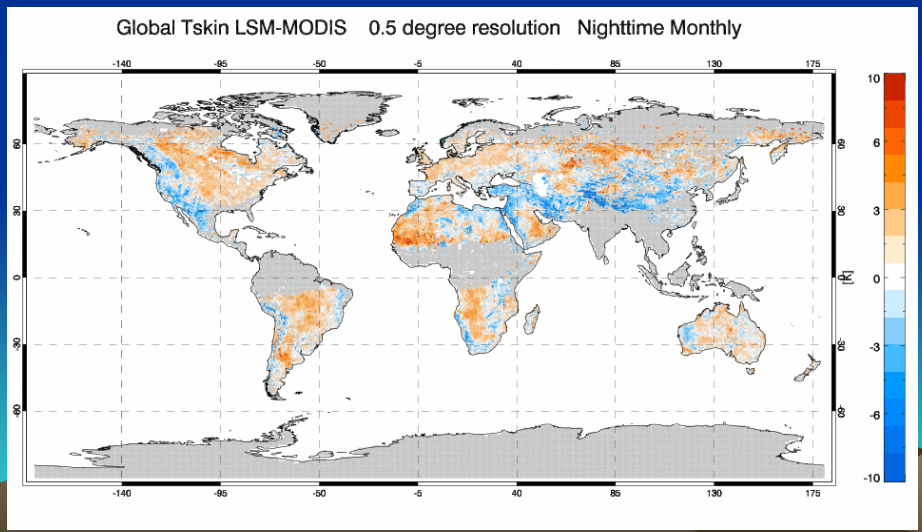
Pending questions

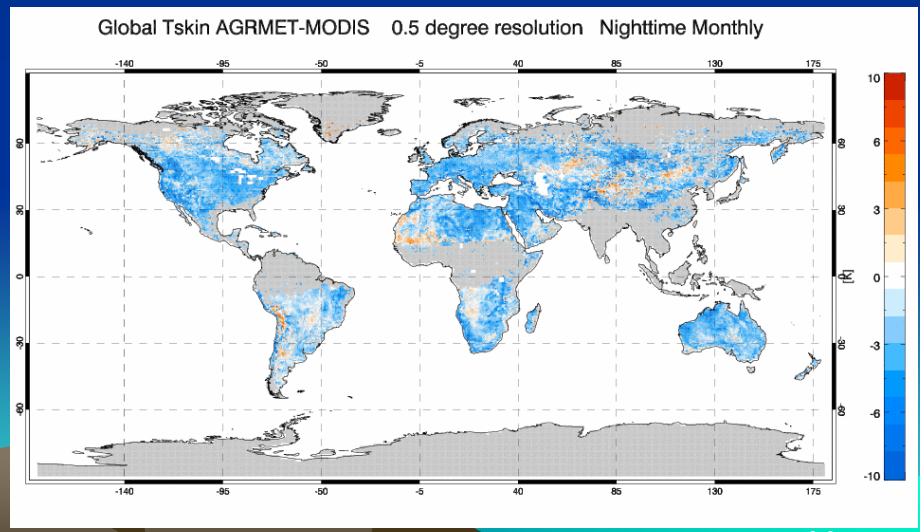
1) Local LST biases: Various LST sources provide significantly different results
   - Sources considered (MODIS, GDAS/NOAH (LSM), AGRMET, AIRS, ISCCP) provide vastly different results especially in the daytime
   - Agreement is better at night than during the day
   - Not much we can do about that aside from ensuring consistency with AMSR-E measurements both spectrally (where atmosphere is sufficiently moist to provide ability of separating LST from emissivity) and in time (including diurnal cycle) over “easy” regions
   - Could be an issue for relating AMSR-E to Prigent SSM/I data (ISCCP LST)
2) Penetration depth/sub-surface temperature gradients
3) Earth gridding/spatial variability errors
4) Azimuthal dependence/terrain slope
5) Emissivity retrieval in regions of quasi-permanent cloud cover
6) Dew?
   - Effect at time of overpass should be minimal – may still check for possible dew based on meteorological conditions
7) Calibration
   - New calibration over land available in 2006?
   - When will reprocessed data be available (current data does not have 89 GHz)?
   - Need to understand calibration process
   - Monitoring of consistency with SSM/I and TMI?
8) MODIS cloud mask (night time)

ISCCP, AGRMET, NOAH vs. MODIS LST

- LST sources agree better at night (here)
- Large discrepancies during day time (next)
- MODIS preferred for timeliness and co-location

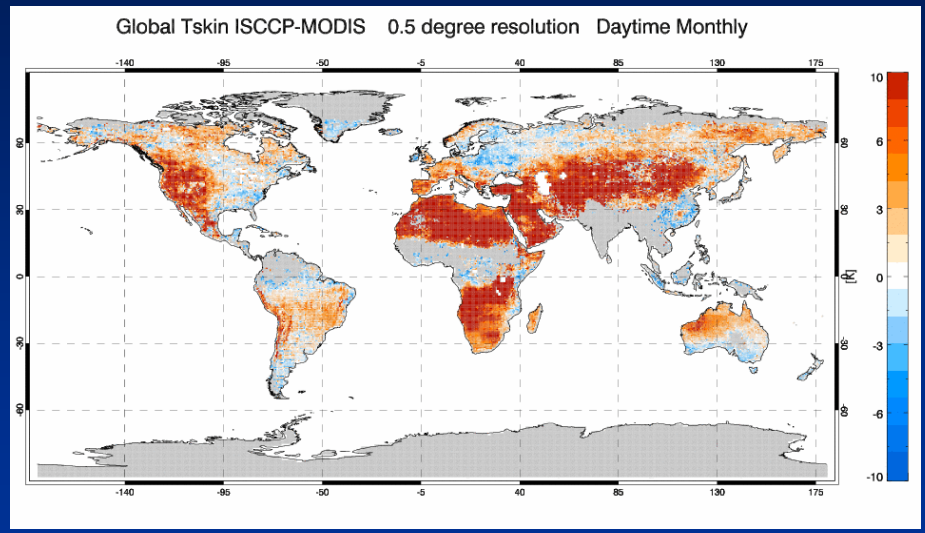


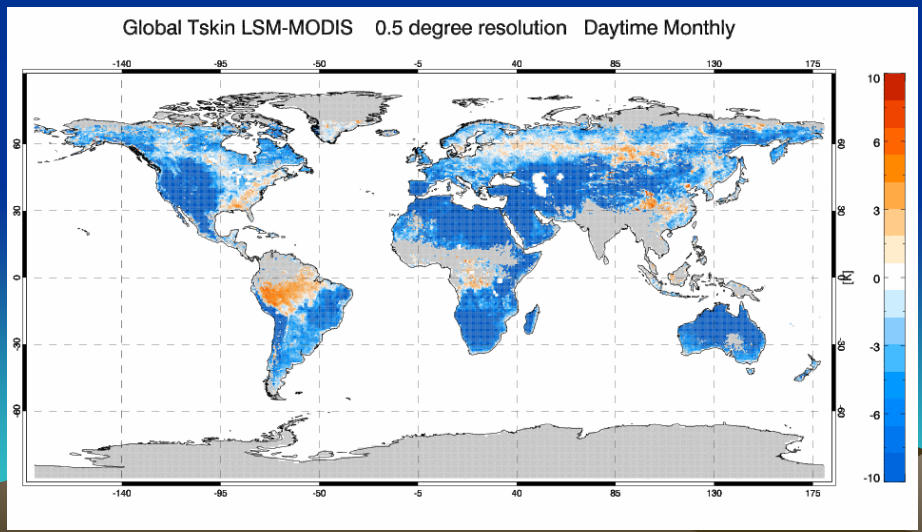


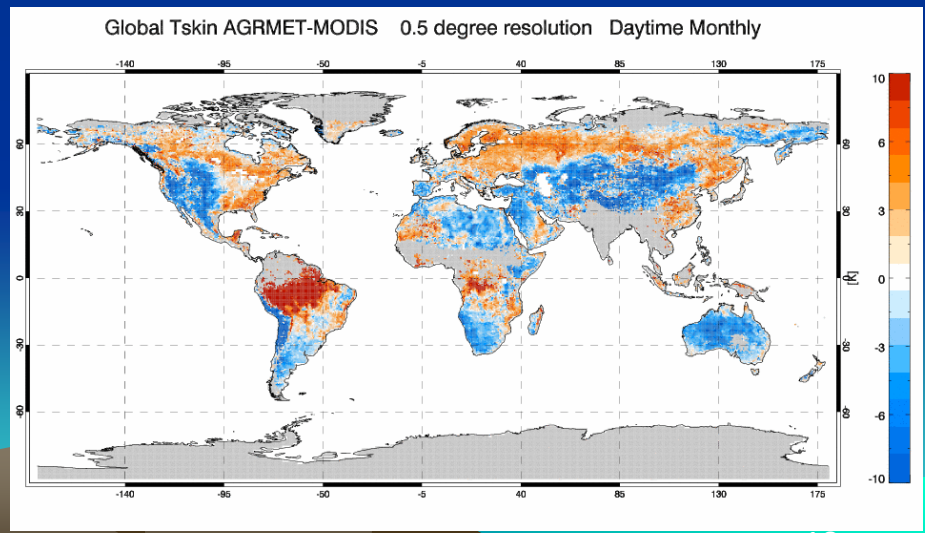


ISCCP, AGRMET, NOAH vs. MODIS LST

- Daytime difference maps

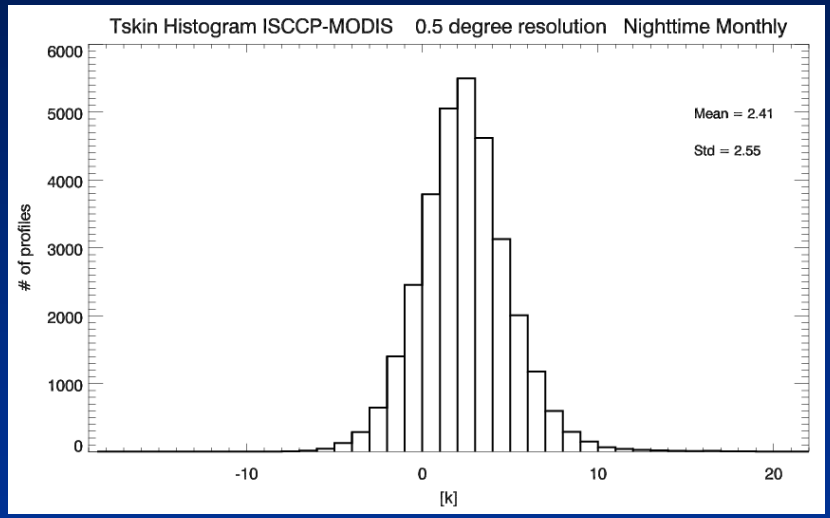


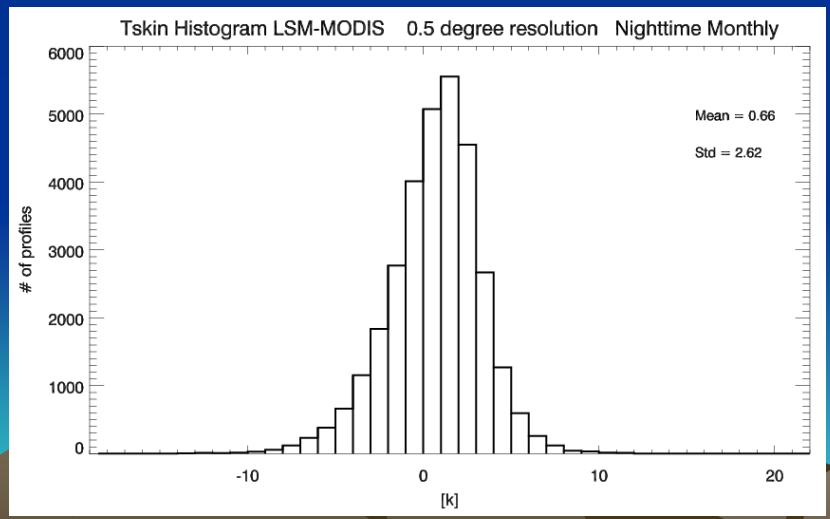


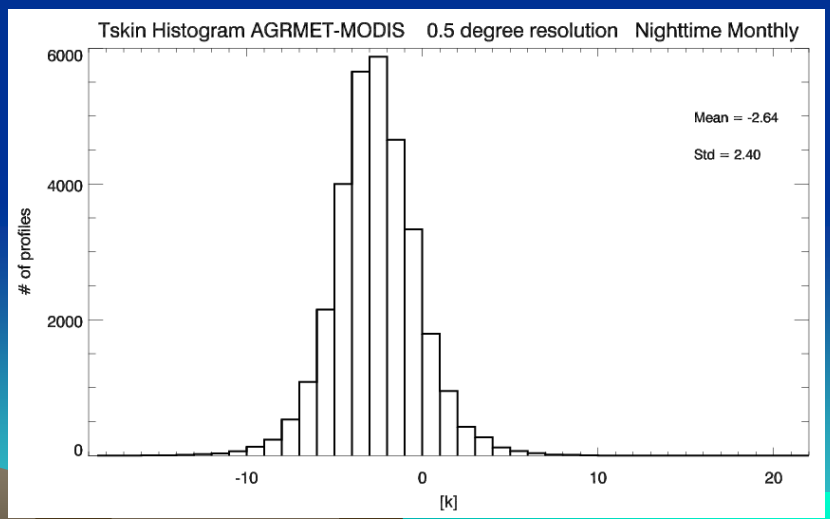


ISCCP, AGRMET, NOAH vs. MODIS LST

- Nighttime difference histograms

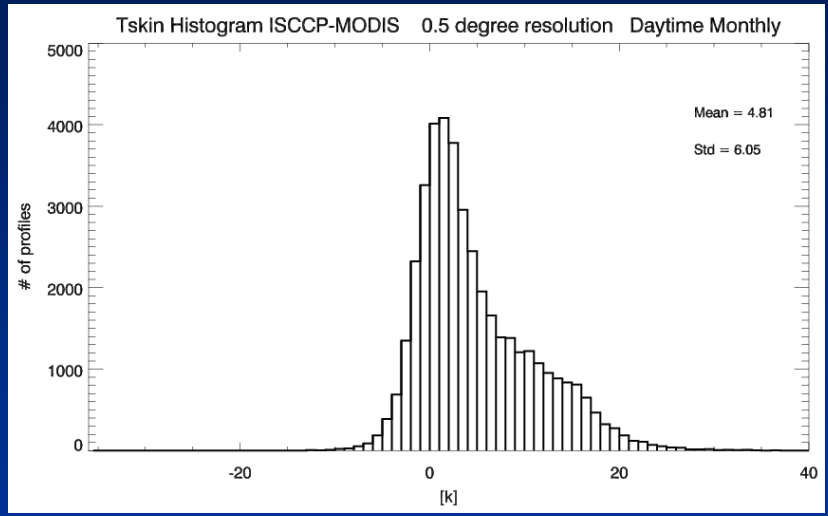


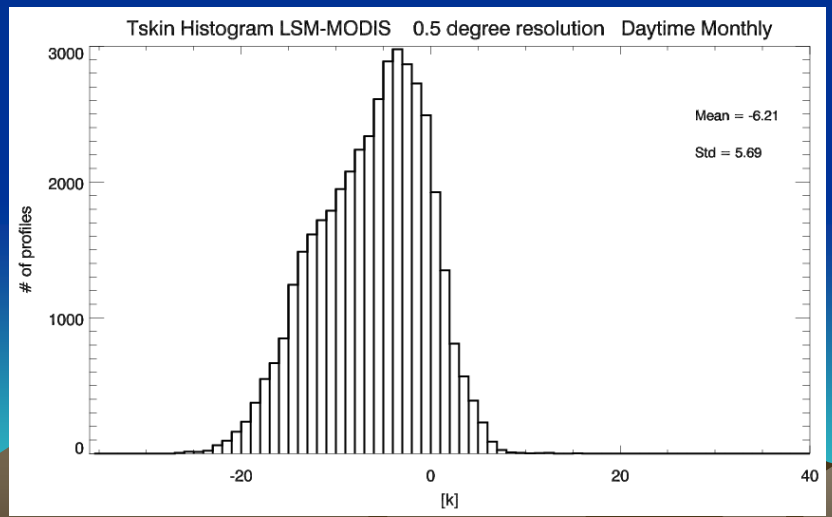


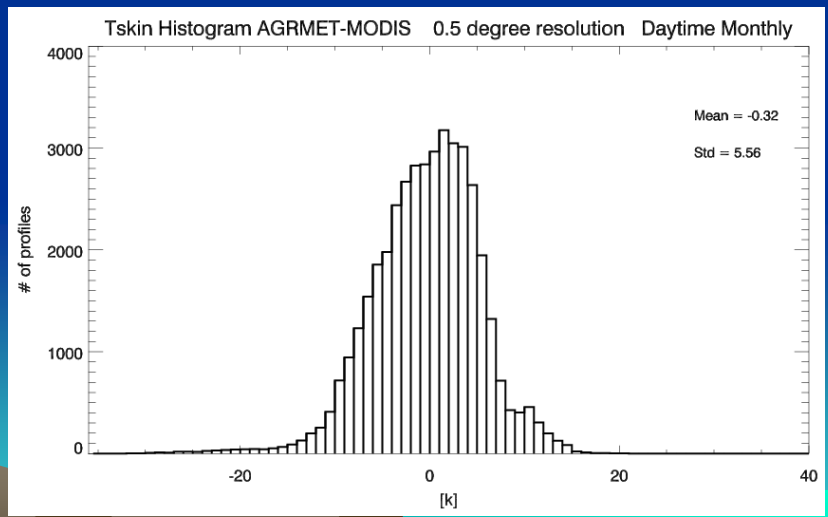


ISCCP, AGRMET, NOAH vs. MODIS LST

- Daytime difference histograms

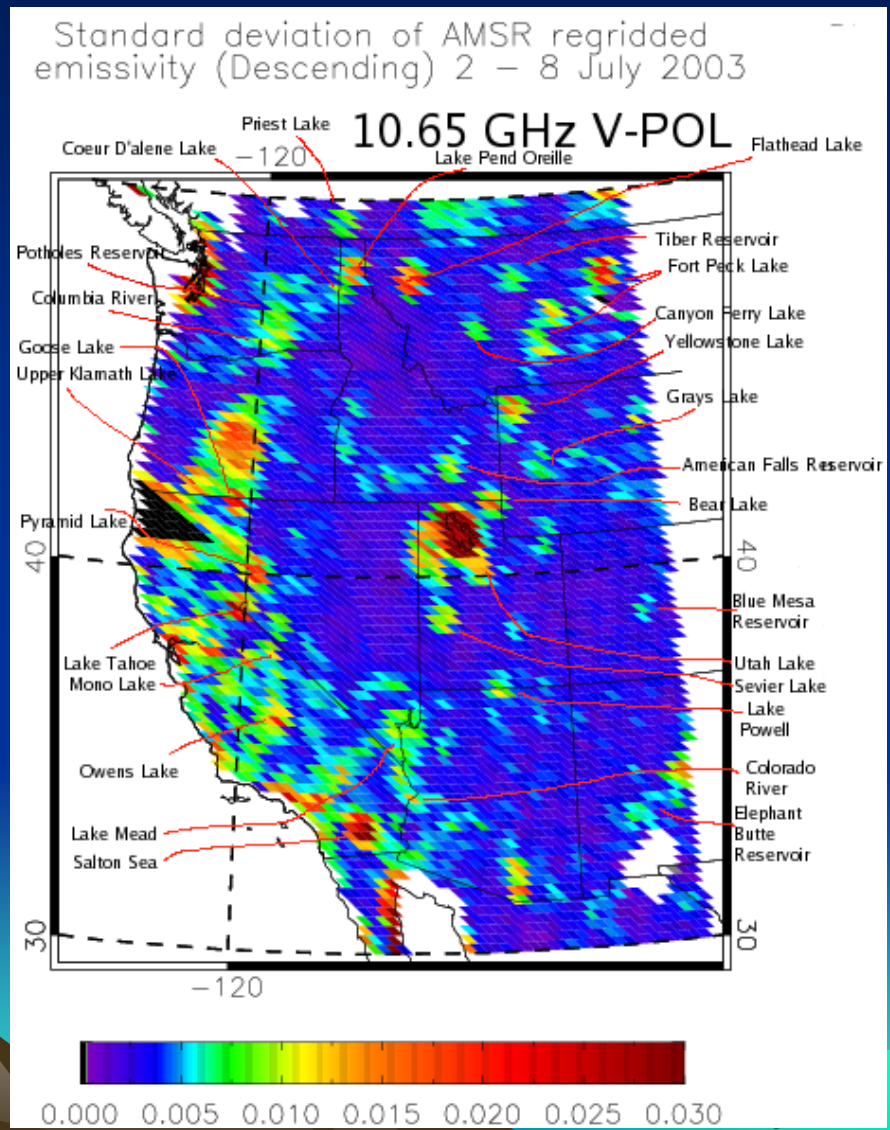




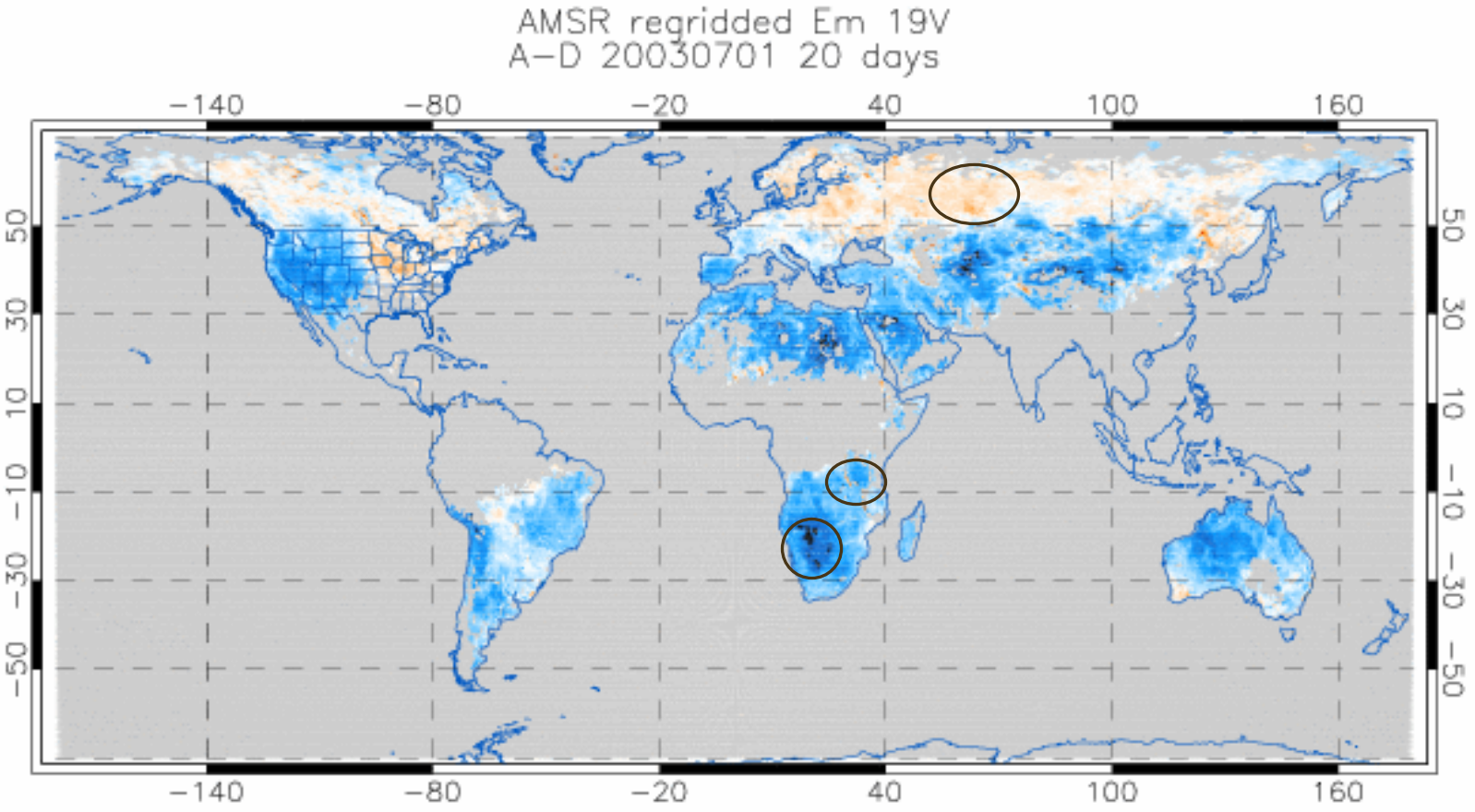


Gridding Errors

- Earth gridding code includes several distance-weighting interpolation methods
- Test results with high-resolution emissivity scenes sampled at 50 km resolution:
  - Gaussian-weighted interpolation has best RMS gridding errors
  - With >0.9 land fraction, RMS emissivity error is < 0.003
  - With 0.1-0.9 land fraction, RMS emissivity error is ~0.012-0.018
- Gridding component of AMSR emissivity retrieval error budget should be comparable
  - Gaussian-weighted interpolation to be added to AMSR processing
  - Should improve retrieval variance especially near coastlines
- Alternative approaches include
  - Water fraction estimate and removal from total emissivity
    - Issue: Water level vary with season
  - Footprint match to fixed Earth grid and perform retrieval afterwards
    - Issue: Clouds

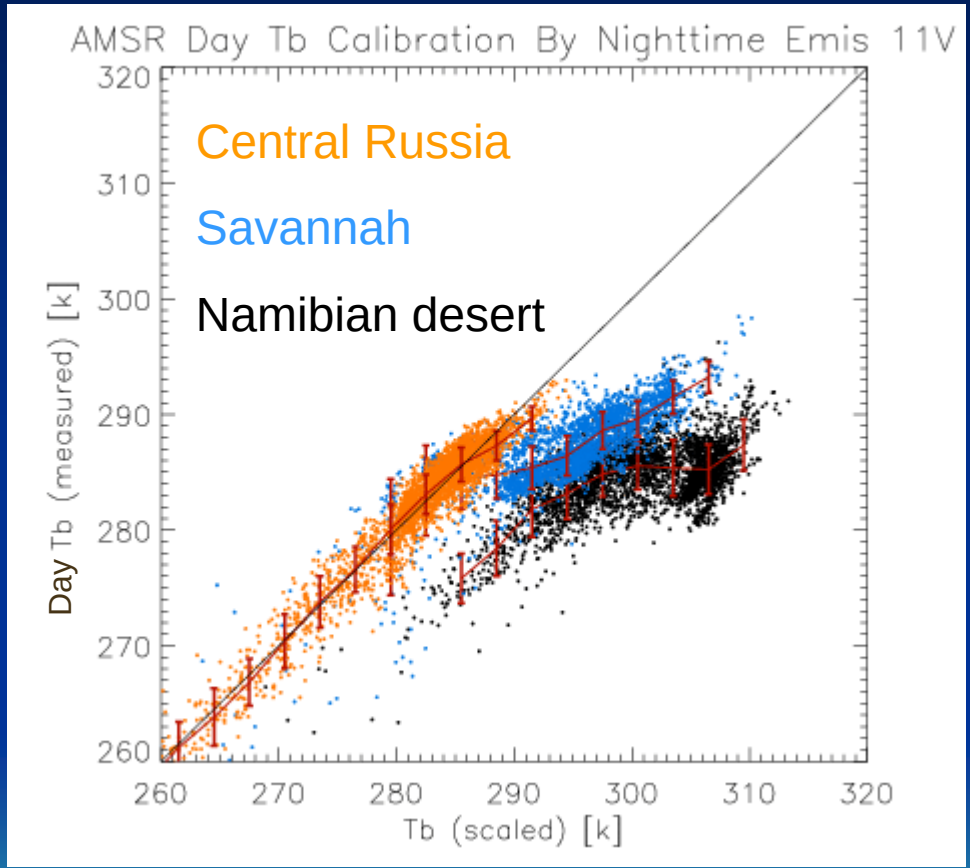


Day-Night AMSR-E Emissivity differences



Day-Night AMSR-E Emissivity differences

- Daytime emissivities much too low over widespread arid/semi-arid areas areas (generally good agreement elsewhere)
  - Most likely due to penetration depth in rock/dry soils/sand/some canopies (?)
- Not observed in previous SSM/I work (Prigent, 1992) outside of sand deserts?
  - Potential reasons are time of the DMSP overpasses (early morning/late afternoon)

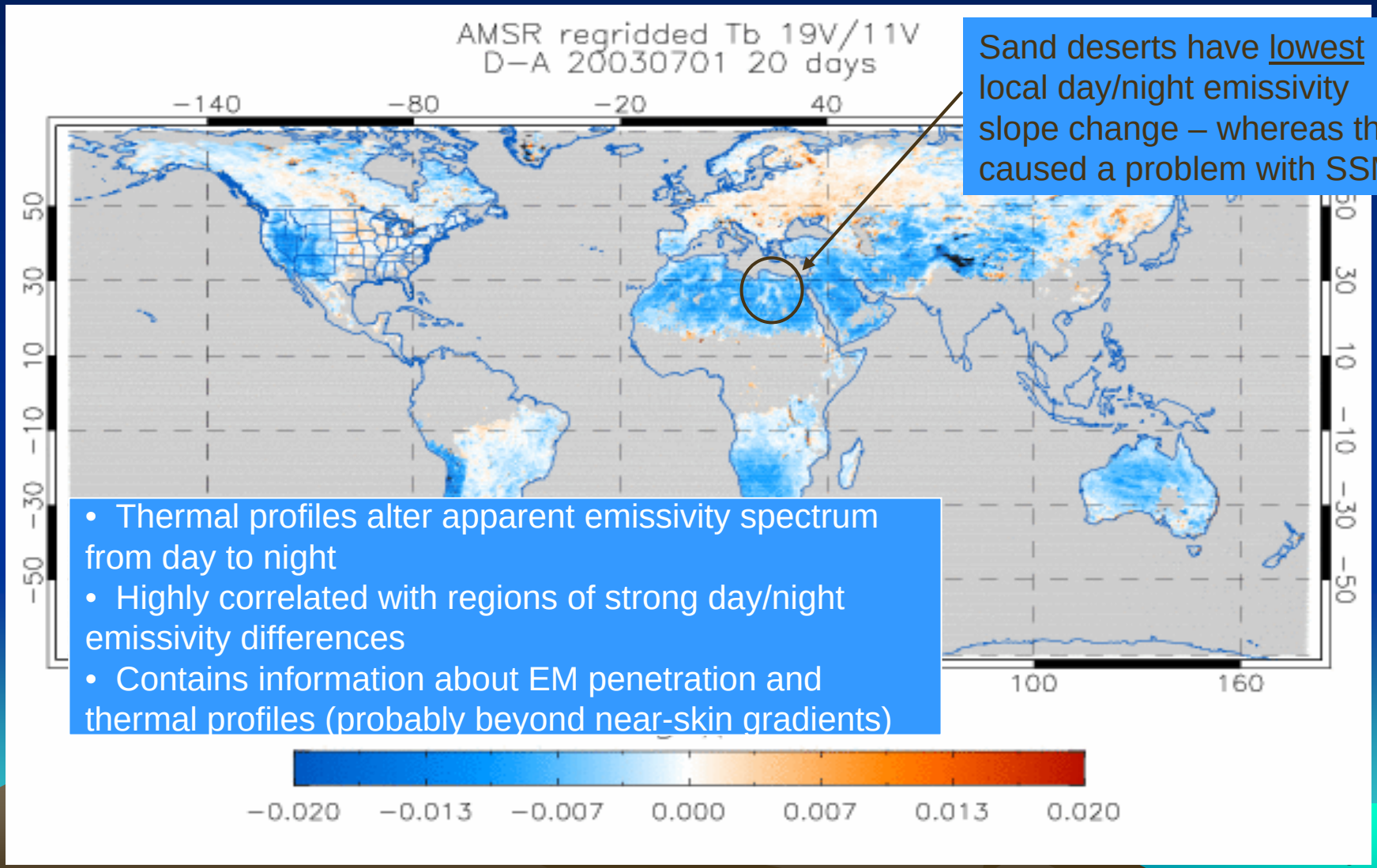


~= e(night)*Ts(day)

High penetration depth areas

- RT equation: $Tb_\nu = T_\nu^\uparrow + \tau_\nu \varepsilon_\nu T_s + \tau_\nu (1-\varepsilon_\nu) T_\nu^\downarrow$ (1)
- Strong sub-surface temperature gradients occur with high surface heat flux conditions
- Day/night change in gradient combined with lower penetration depth at higher frequency causes changes in the "apparent" emissivity spectrum retrieved from (1), i.e. (1) is invalid
- Penetration depth may reach ~20 cm at 19 GHz in dry sandy areas (Prigent, 1999)
- Preliminary static maps of high penetration depth
  - Based on diurnal change in Tb slope in V-pol.
  - 19V/11V and 37V/19V Tb ratios considered

Night-Day TB slope difference



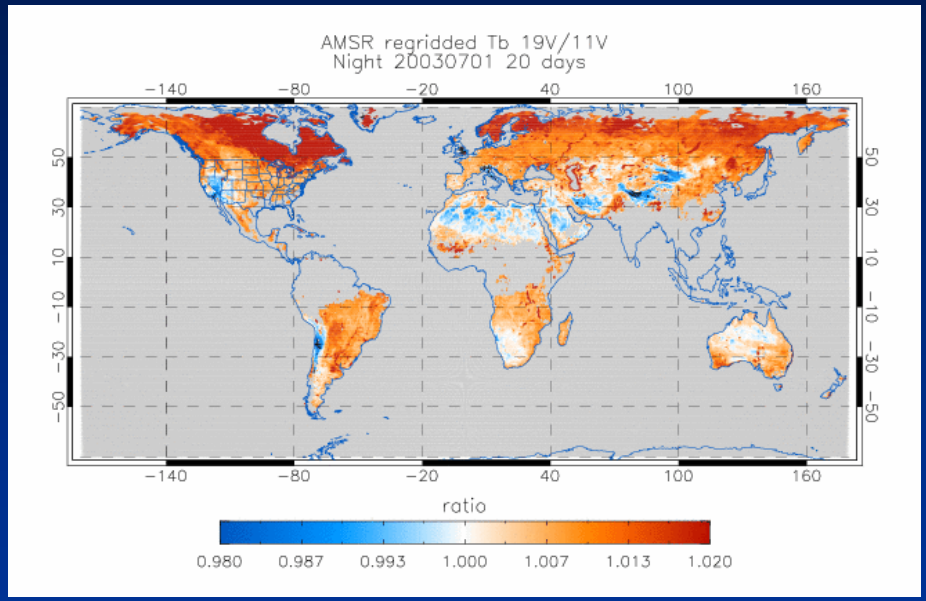
Sand deserts have lowest local day/night emissivity slope change – whereas they caused a problem with SSM/I

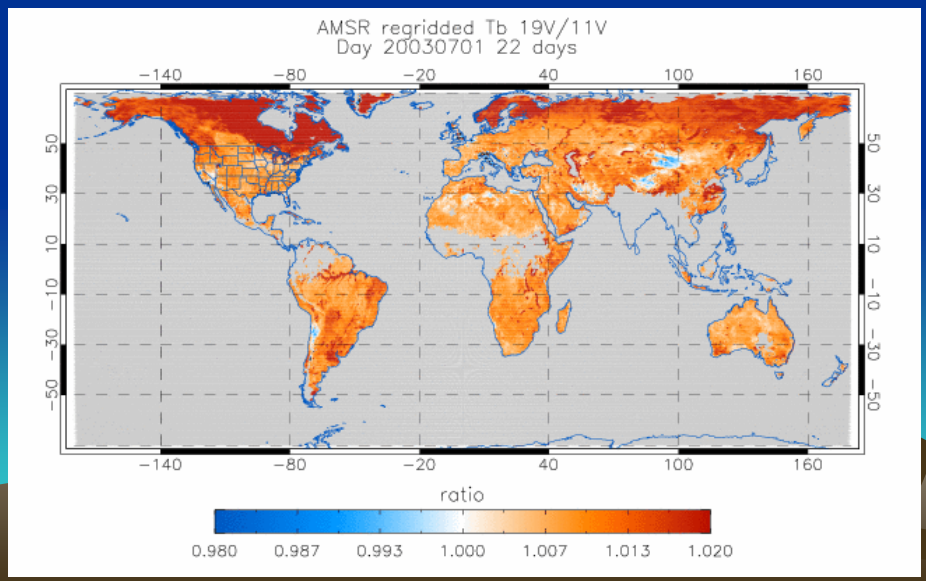
- Thermal profiles alter apparent emissivity spectrum from day to night
- Highly correlated with regions of strong day/night emissivity differences
- Contains information about EM penetration and thermal profiles (probably beyond near-skin gradients)

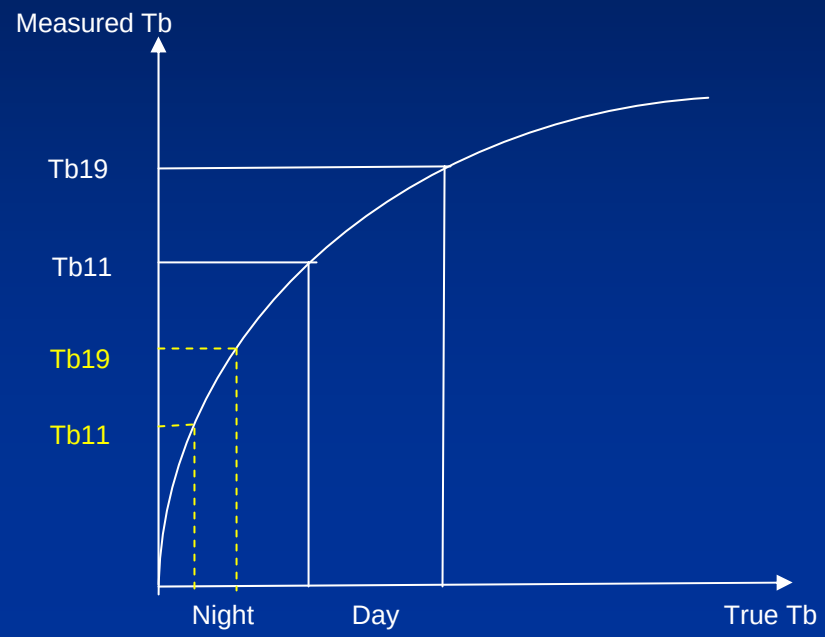
Automated temporal/spectral cluster analysis

- Full spectral and time (~2 weeks) dimensions taken into account
- Removal of atmospheric effects and correction of NCEP/GDAS first-guess
- LST-independent
  - Assumption is that impact of ΔLST on emissivity spectrum differs from impact of other factors
  - Flagging based on cluster analysis
- Uses information content of AMSR measurements to verify that input LST is within allowable range

Calibration?







- Even severe calibration problems should not change sign of 11-19 GHz slope

Future (near-term) work

- Investigate possibility of adding SSM/I (TMI?)
  - Ensures continuity with heritage SSM/I work (provides comparison with SSM/I and AMSR)
  - Increased temporal sampling (adds early morning and late afternoon passes)
  - Issues re. ISCCP (used for SSM/I) vs. MODIS LST? Differences minimized at local time of SSM/I orbit.
- Assess feasibility of modeling sub-surface effects (penetration depth, thermal conductivity,…etc)
  - Need capability to estimate penetration depth and/or temperature profile
  - NOAH model could be a good starting point (parameterized thermal conduction) and surface emissivity / albedo (cooling/heating)
  - Use times with small sub-surface gradient to infer emissivity (night?)
  - Use other times to assess penetration depth (stable in time as long as emissivity does not change)
- Refine error flagging (difficult terrain, emissivity change detection) and assess time variability
- Cloudy retrievals (model is only source for Ts)